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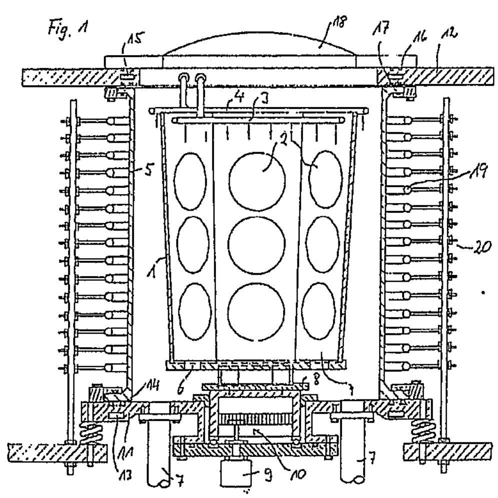
(56) Für die Beurteilung der Patentfähigkeit in Betracht gezogene Druckschriften:

DE-OS 35 25 870
Solid State Technology, May 1986, pp 160, 162;

(54) Vorrichtung und Verfahren zum epitaktischen Abscheiden von insbesondere Halbleitermaterial auf Siliziumscheiben aus der Gasphase

Die Erfindung betrifft eine Vorrichtung und ein Verfahren zum epitaktischen Abscheiden von Halbleitermaterial auf Halbleiterscheiben (2). Die Halbleiterscheiben (2) sind im Innenraum eines Suszeptors (1) so angeordnet, daß die Oberfläche jeweils einer Halbleiterscheibe zur Oberfläche einer anderen Halbleiterscheibe parallel liegt.

Fig. 1



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Beschreibung

Die Erfindung betrifft eine Vorrichtung und ein Verfahren zum epitaktischen Abscheiden von insbesondere Halbleitermaterial auf Siliziumscheiben aus der Gasphase nach dem Oberbegriff des Patentanspruches 1 bzw. 10.

Vorrichtungen zum epitaktischen Abscheiden von Halbleitermaterial auf Halbleiterscheiben, welche auch als Epitaxie -Reaktoren bezeichnet werden, sind seit Jahren in den verschiedensten Ausführungen bekanntgeworden (vgl. "Solid-State Technology", Mai 1986, Seiten 160, 162): So sind beispielsweise bei einem ersten bekannten Epitaxie-Reaktor (a.a.O. Seite 160), die Halbleiterscheiben auf der äußeren Mantelfläche eines einen mehreckförmigen Querschnitt aufweisenden Suszeptors gelagert, der drehbar im Innenraum einer Glocke angebracht ist. Die Glocke ist ihrerseits von einer Induktionsheizspule umgeben und wird von oben nach unten mit Gas durchströmt, das beispielsweise Wasserstoff, Siliziumtetrachlorid, Dichlorsilan und ggf. ein Dotiergas enthält.

Die Drehung des Suszeptors erfolgt, um die Halbleiterscheiben möglichst gleichmäßig sowohl dem Gas als auch der Wärmestrahlung auszusetzen, so daß die epitaktischen Schichten auf den Halbleiterscheiben möglichst spannungsfrei und ohne Defekte aufwachsen.

Bei anderen bekannten Epitaxie-Reaktoren (a.a.O. Seite 162) werden die Außenflächen der inneren Quarzglocke mit einer dünnen Reflexionsschicht aus beispielsweise aufgedampften Gold beschichtet, so daß die von den Halbleiterscheiben abgestrahlte Infrarotstrahlung wieder zurück auf die Scheiben geworfen wird. Bei derart gestalteten Epitaxie-Reaktoren muß aber dafür gesorgt werden, daß die Innenfläche der Glocke wesentlich kühler wird als die auf dem Suszeptor gelagerten Scheiben. Wird nämlich die Innenfläche der Glocke annähernd so warm wie die Halbleiterscheiben, so kann sich auch Halbleitermaterial auf dieser Innenfläche niederschlagen, was die Funktionsfähigkeit des Epitaxie-Reaktors erheblich beeinträchtigt.

Bei einem anderen bekannten Epitaxie-Reaktor-Typ (a.a.O. Seiten 160 und 162) ist der Suszeptor tellerförmig gestaltet und ebenfalls in einer Glocke drehbar gelagert. Die Induktionsheizspule befindet sich hier auf der Unterseite des Tellers, auf dessen Oberseite die Halbleiterscheiben aufliegen. Die Glocke ist von einem sägezahnartig abgestuften Reflektor im Abstand umgeben, der wiederum — wie im vorhergehenden Beispiel — die abgestrahlte Wärme zurück auf die Halbleiterscheiben wirft.

Bei einem dritten Typ eines bekannten Epitaxie-Reaktors (a.a.O. Seite 162) sind die Halbleiterscheiben wie im ersten Beispiel senkrecht gelagert. Sie sind hier aber im Gegensatz zum ersten Beispiel mit ihren Oberflächen parallel zur Radialrichtung und nicht parallel zur Mantelfläche des Suszeptors angeordnet. Im übrigen ist bei diesem dritten Typ von bekannten Epitaxie-Reaktoren die den Suszeptor aufnehmende Glocke von einer Widerstandsheizung im wesentlichen auf ihrer Mantelfläche umgeben.

Schließlich ist ein Epitaxie-Reaktor bekannt (vgl. DE-OS 35 25 870), bei dem ähnlich wie bei dem eingangs beschriebenen Typ Halbleiterscheiben auf der äußeren Mantelfläche eines einen mehreckförmigen Querschnitt aufweisenden Suszeptors gelagert sind. Um die Glocke sind mehrere Schirme angeordnet, welche abgestrahlte Strahlung zurück auf die Halbleiterscheiben reflektieren.

Allen diesen bekannten Epitaxie-Reaktoren ist gemeinsam, daß gesonderte Vorkehrungen mit Beschichtungen der Glocke oder zusätzlichen Reflektoren und Schirmen getroffen werden müssen, damit eine möglichst gleichmäßige Temperaturverteilung für die einzelnen Scheiben bei geringem Wärmeverlust sichergestellt werden kann.

Es ist nun Aufgabe der vorliegenden Erfindung, die Vorrichtung und das Verfahren der eingangs genannten Art so zu verbessern, daß mit möglichst wenig Aufwand und insbesondere ohne derartige zusätzliche Maßnahmen, wie Reflektoren, Infrarotlampen, Infrarotstrahler usw. eine Aufheizung der Halbleiterscheiben ohne Erzeugung von mechanischen und thermischen Spannungen in diesen möglich wird.

Diese Aufgabe wird bei einer Vorrichtung nach dem Oberbegriff des Patentanspruches 1 bzw. bei einem Verfahren nach dem Oberbegriff des Patentanspruches 10 erfindungsgemäß durch die in den jeweiligen kennzeichnenden Teilen enthaltenen Merkmale gelöst.

Bei der erfindungsgemäßen Vorrichtung werden also in vollkommener Abkehr vom bisherigen Stand der Technik die Halbleiterscheiben auf der inneren Mantelfläche des Suszeptors und nicht auf dessen äußerer Mantelfläche gelagert, so daß sie sich gegenseitig spiegeln. Bei beispielsweise einem sechseckförmigen Querschnitt des Suszeptors können dann die Halbleiterscheiben auf einfache Weise so angebracht werden, daß die freie Oberfläche einer Halbleiterscheibe jeweils der freien Oberfläche einer anderen Halbleiterscheibe gegenüberliegt.

Damit wird im wesentlichen die gesamte, von einer Halbleiterscheibe abgestrahlte Wärmestrahlung auf die jeweils gegenüberliegende Halbleiterscheibe geworfen, so daß die Halbleiterscheiben alle äußerst gleichmäßig und ohne wesentliche Wärmeverluste aufgeheizt werden können. Es sind keine zusätzlichen Reflektoren oder die Gleichmäßigkeit der Gasströmung beeinträchtigende Halterungen erforderlich. Das Gas strömt äußerst gleichmäßig durch den Innenraum des Suszeptors, auf dessen Innenfläche die Halbleiterscheiben gelagert sind. Diese können mittels eines Roboters angebracht werden.

Vorteilhafte Weiterbildungen der Erfindung ergeben sich insbesondere aus den Patentansprüchen 2 bis 9 und 11.

Nachfolgend wird die Erfindung anhand der Zeichnungen näher erläutert. Es zeigen:

Fig. 1 einen Schnitt durch die erfindungsgemäße Vorrichtung und

Fig. 2 eine verkleinerte Draufsicht auf die Vorrichtung von **Fig.** 1.

Fig. 1 zeigt einen Epitaxie-Reaktor mit einem Suszeptor **1** aus Graphit, der beidseitig mit einem dünnen Siliziumcarbidfilm beschichtet ist, um so sicherzustellen, daß kein störendes Fremdmaterial vom Suszeptor **1** absorbiert und später wieder abgegeben wird (Degasierungseffekt). Auf der inneren Mantelfläche des Suszeptors **1** sind Halbleiterscheiben **2** aus Silizium angebracht. Diese Halbleiterscheiben **2** können beispielsweise durch einen Roboter in den Suszeptor **1** eingebracht werden.

Am oberen Ende des Suszeptors **1** befindet sich eine als Gaseinlaß dienende Ringdüse **3** in der Form eines kreisförmigen Rohres, an dessen Unterseite in regelmäßigen Abständen Düsen bildende, kleine Löcher angebracht sind. Aus dieser Ringdüse **3** strömt das Prozeßgas, also Wasserstoff, Siliziumtetrachlorid, Dichlorsilan

und Dotiergas in das Innere des Suszeptors **1** über die an dessen inneren Mantelfläche angebrachten Halbleiterscheiben **2**.

Außerdem ist an der Oberseite des Suszeptors **1** eine ähnlich wie die Ringdüse **3** gestaltete Ringdüse **4** für das Spülgas, nämlich Stickstoff oder Wasserstoff vorgesehen. Dieses Spülgas strömt zwischen der Außenfläche des Suszeptors **1** und der inneren Mantelfläche eines Behälters in der Form eines Quarzzylinders **5**, welcher den Suszeptor **1** im Abstand umgibt. Die Ringdüsen **3**, **4** bilden eine Gaseinlaßeinrichtung zum Zuführen von Gas in den Behälter. An der Unterseite des Suszeptors sind Gasauslaßöffnungen **6** vorgesehen, über die das Prozeßgas aus dem Suszeptor **1** in den Raum zwischen der Außenfläche des Suszeptors **1** und der inneren Mantelfläche des Quarzzylinders **5** eintritt. Dort vermischt sich das Prozeßgas mit dem in dem Raum zwischen der äußeren Mantelfläche des Suszeptors **1** und der inneren Mantelfläche des Quarzzylinders **5** strömenden Spülgas, um zusammen mit diesem den Reaktor über als Gasauslaß dienende Quarzrohre **7** zu verlassen, die evtl. auch an eine Unterdruckpumpe angeschlossen sind.

Der Suszeptor **1** ist über eine Quarzplatte **8** drehbar gelagert und wird durch einen Motor **9** über ein Zahngetriebe **10** in Drehung versetzt.

Die Oberseite und die Unterseite des Quarzzylinders **5** ist jeweils durch eine Edelstahlplatte **11** bzw. **12** abgeschlossen. In der Edelstahlplatte **11** befindet sich ein Kühlkanal **13**, in welchem ein Kühlmittel fließt, um eine Dichtung **14** zwischen dem unteren Flansch des Quarzzylinders **5** und der unteren Edelstahlplatte **11** zu kühlen.

In ähnlicher Weise weist die obere Edelstahlplatte **12** einen Kühlkanal **15** auf, der Dichtungen **16** zwischen der oberen Edelstahlplatte **12** und einer Quarzabdeckung **18** bzw. zwischen der oberen Edelstahlplatte **12** und dem oberen Flansch des Quarzzylinders **5** kühlt.

Die äußere Mantelfläche des Quarzzylinders **5** ist von einer Induktionsheizspule in der Form einer Hochfrequenzspule **19** umgeben, welche an einer Halterung **20** befestigt ist.

Bei Niederdruckepitaxie-Prozessen wird durch eine Niederdruckpumpe im Innenraum des Quarzzylinders **5** und damit auch im Innenraum des Suszeptors **1** ein Niederdruck in der Größenordnung von 23 300 Pa (175 Torr) bis 26 600 Pa (200 Torr) aufrechterhalten. Die Hochfrequenzspule **19** heizt den aus Graphit bestehenden und beidseitig mit Siliziumfilmen beschichteten Suszeptor **1** auf. Prozeßgas wird über die Ringdüse **3** in den Innenraum des Suszeptors **1** eingegeben, an dessen innerer Mantelfläche die Halbleiterscheiben **2** durch einen Roboter angebracht wurden.

Gleichzeitig wird Spülgas über die Ringdüse **4** in den Innenraum des Quarzzylinders **5** eingebracht.

Selbstverständlich werden diese Schritte erst vorgenommen, nachdem die Halbleiterscheiben **2** auf eine für die Epitaxie ausreichende Temperatur durch die Hochfrequenzspule **19** aufgeheizt wurden. Während der Epitaxie wird der Suszeptor **1** durch den Motor **9** über das Zahngetriebe **10** in Drehung versetzt, so daß alle Halbleiterscheiben **2** äußerst gleichmäßig der Induktionsheizung durch die Hochfrequenzspule **19** ausgesetzt sind.

Der Suszeptor **1** hat einen rechteckförmigen Querschnitt, so daß die einzelnen Halbleiterscheiben **2** jeweils einer anderen Halbleiterscheibe gegenüberliegen. Dadurch ist sichergestellt, daß die von einer Halbleiterscheibe abgestrahlte Wärme im wesentlichen auf die gegenüberliegende Halbleiterscheibe auftrifft. Hierdurch wird erreicht, daß die einzelnen Halbleiterscheiben **2** möglichst gleichmäßig aufgeheizt werden und keine besonderen, zusätzlichen Reflektoren erforderlich sind. Durch die Anordnung der Halbleiterscheiben **2** im Innenraum des Suszeptors **1** ist außerdem sichergestellt, daß die Teile des Reaktors, die dem Prozeßgas ausgesetzt sind, nur durch Flächen gebildet werden, auf denen sich auch Halbleiterscheiben befinden. Mit anderen Worten, es gibt keine wärmeren Teile des Reaktors, an denen das Prozeßgas vorbeiströmt, so daß keine zusätzlichen Maßnahmen für die Kühlung beispielsweise der Innenwand des Quarzzylinders **5** erforderlich sind.

Anstelle eines Suszeptors mit einem sechseckförmigen Querschnitt kann selbstverständlich auch ein Suszeptor verwendet werden, der eine geradzahlige Vielzahl von Ecken besitzt. Von Bedeutung ist lediglich, daß jeweils eine Halbleiterscheibe einer anderen Halbleiterscheibe gegenüberliegt, wobei die Oberflächen dieser Halbleiterscheiben möglichst parallel zueinander verlaufen.

Zur besseren Halterung der einzelnen Halbleiterscheiben **2** sind die Wände des Suszeptors **1** geringfügig von oben nach unten geneigt, wobei der Suszeptor **1** oben eine größere Querschnittsfläche als unten besitzt. Dadurch wird aber die Parallelität der Oberflächen gegenüberliegender Halbleiterscheiben **2** praktisch nicht beeinflußt.

Die Erfindung schafft so einen Epitaxie-Reaktor der sich durch zahlreiche Vorteile auszeichnet:

(a) Es brauchen keine gesonderten Maßnahmen getroffen zu werden, um durch Reflexion von Wärmestrahlung für eine möglichst gleichmäßige Aufheizung der Halbleiterscheiben und damit für ein spannungsfreies Aufwachsen epitaktischer Schichten zu sorgen, da diese Reflexion von den gegenüberliegenden Flächen der Halbleiterscheiben erfüllt wird.

(b) Durch die Anbringung der Halbleiterscheiben **2** im Innenraum des Suszeptors **1** wird gewährleistet, daß keine wärmeren Teile als die Halbleiterscheiben **2** dem Prozeßgasstrom ausgesetzt sind. Dies bedeutet wiederum, daß keine zusätzlichen Kühlmaßnahmen getroffen werden müssen, um ein unerwünschtes Abscheiden von Halbleitermaterial auf noch wärmeren Teilen als den Halbleiterscheiben **2** zu verhindern.

(c) Der Epitaxie-Reaktor kann einfach mit Halbleiterscheiben bestückt werden, indem die Quarzabdeckung **18** abgenommen wird und die Halbleiterscheiben **2** beispielsweise durch einen Roboter in den Innenraum des Suszeptors **1** eingebracht werden.

Patentansprüche

1. Vorrichtung zum epitaktischen Abscheiden von insbesondere Halbleitermaterial auf Scheiben (**2**) aus der Gasphase, mit:
   - einem Behälter (**5**), in dem auch ein Unterdruck erzeugbar ist,
   - einem im Behälter (**5**) angeordneten Suszeptor (**1**) zur Halterung der Scheiben (**2**),
   - einer Gaseinlaßeinrichtung (**3**, **4**) zum Zuführen von Gas in den Behälter (**5**),
   - einem Gasauslaß (**7**) und
   - einer Induktionsheizspule (**19**) zum Erwärmen des Suszeptors (**1**) und der Scheiben (**2**) im Innenraum des Behälters (**5**),

dadurch gekennzeichnet, daß

– die Scheiben (2) derart im Suszeptor (1) angeordnet sind, daß jeweils eine Scheibe mit ihrer freien Oberfläche zur freien Oberfläche einer gegenüberliegenden Scheibe im wesentlichen parallel ist, so daß die auf die eine Scheibe eingestrahlte und an dieser reflektierte Strahlung zur anderen Scheibe geworfen wird und umgekehrt.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Scheiben auf der Innenwand des Suszeptors (1) angebracht sind.

3. Vorrichtung nach Anspruch 2, dadurch gekennzeichnet, daß der Querschnitt des Suszeptors (1) die Form eines regelmäßigen Vielecks mit n Ecken hat, wobei n vorzugsweise geradzahlig ist.

4. Vorrichtung nach Anspruch 3, dadurch gekennzeichnet, daß $n=6$ gilt.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß der Suszeptor (1) beidseitig mit Siliziumcarbid beschichtet ist.

6. Vorrichtung nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß der Suszeptor (1) im Behälter (5) drehbar gelagert ist.

7. Vorrichtung nach einem der Ansprüche 1 bis 6, dadurch gekennzeichnet, daß der Suszeptor (1) aus reinem Graphit mit Siliziumcarbid-Beschichtung besteht.

8. Vorrichtung nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß die Gaseinlaßeinrichtung (3, 4) einen Gaseinlaß zum Zuführen von Spülgas in den Behälter (5) und einen Gaseinlaß (3) zum Zuführen von Prozeßgas in den Suszeptor (1) hat.

9. Vorrichtung nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet, daß die Innenwände des Suszeptors (1) von oben nach unten geringfügig nach innen geneigt sind.

10. Verfahren zum epitaktischen Abscheiden von insbesondere Halbleitermaterial auf Siliziumscheiben (2) aus der Gasphase, bei dem:

– in einem Behälter (5) atmosphärischer Druck herrscht, aber auch Unterdruck erzeugt werden kann,

– Scheiben in einem im Behälter (5) angeordneten Suszeptor (1) gehalten werden,

– über eine Gaseinlaßeinrichtung (3, 4) Gas in den Behälter (5) eingeführt wird und

– die Scheiben im Innenraum des Suszeptors (1) mittels einer Induktionsheizspule (19) erwärmt werden, dadurch gekennzeichnet, daß

– die Scheiben (2) derart im Suszeptor (1) angeordnet werden, daß jeweils eine Scheibe mit ihrer freien Oberfläche zur freien Oberfläche einer gegenüberliegenden Scheibe im wesentlichen parallel ist, so daß die auf die eine Scheibe eingestrahlte und an dieser reflektierte Strahlung zur anderen Scheibe geworfen wird und umgekehrt.

11. Verfahren nach Anspruch 10, dadurch gekennzeichnet, daß im Behälter (5) sowohl atmosphärischer Druck wie auch ein Unterdruck von 23 300–26 600 Pa aufrechterhalten wird.

Hierzu 1 Seite(n) Zeichnungen

– Leerseite –

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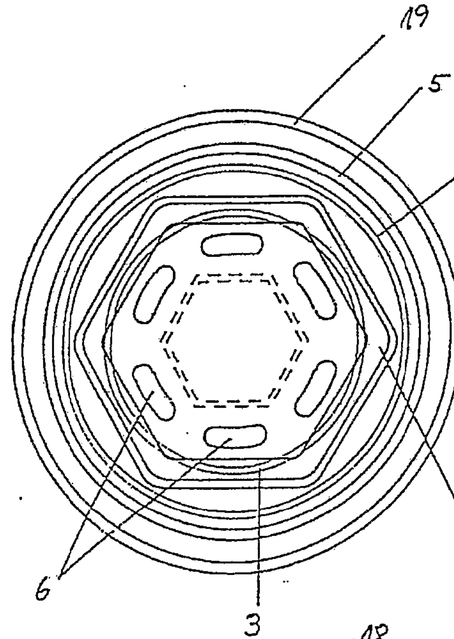
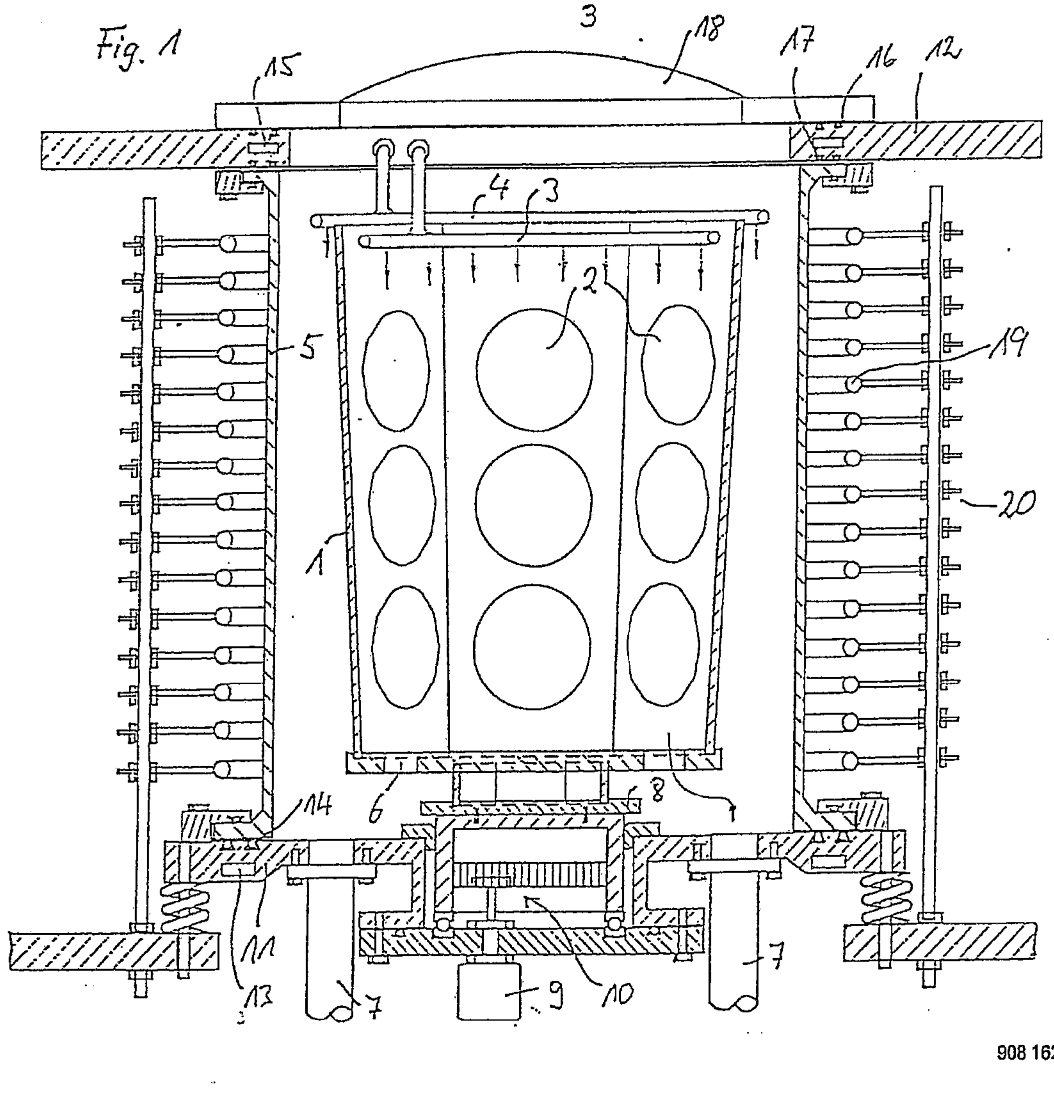


Fig. 2

Fig. 1



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(56) Publications considered in evaluating patentability:
DE-OS 35 25 870
Solid State Technology, May 1986, pp. 160, 162.

(54) Device and Process for the Epitactic Deposition of Material, Especially Semiconductor Material, on Silicon Wafers from the Gas Phase

The invention pertains to a device and to a process for the epitactic deposition of semiconductor material onto semiconductor wafers (2). The semiconductor wafers (2) are arranged in the interior of a susceptor (1) in such a way that the surface of each semiconductor wafer is parallel to the surface of another semiconductor wafer.

Specification

The invention pertains to a device and to a process for the epitactic deposition of material, especially semiconductor material, onto silicon wafers from the gas phase according to the introductory clauses of Claim 1 and Claim 10, respectively.

Devices for the epitactic deposition of semiconductor material onto semiconductor wafers, also called epitaxial reactors, have been known for many years and have many different forms (compare "Solid State Technology", May 1986, pp. 160, 162). For example, in a first known epitaxial reactor (op. cit., p. 160), the semiconductor wafers are supported on the outer lateral surface of a susceptor with a polygonal cross section, which is installed with freedom of rotation inside a bell. The bell itself is surrounded by an induction heating coil, and a gas, which contains, for example, hydrogen, silicon tetrachloride, dichlorosilane, and possibly a doping gas, flows through the bell from top to bottom.

The susceptor is rotated so that the semiconductor wafers are exposed as uniformly as possible both to the gas and also to the thermal radiation, so that the epitactic layers formed on the semiconductor disks will be as free as possible of stresses and will grow without defects.

In other known epitaxial reactors (op. cit., page 162), the outer surfaces of the inner quartz bell are coated with a thin reflective layer of, for example, vapor-deposited gold, so that the infrared radiation emitted by the semiconductor wafers is reflected back onto the wafers again. In epitaxial reactors designed in this way, however, care must be taken to ensure that the inside surface of the bell is much cooler than the wafers supported on the susceptor. If the inside surface is at approximately the same temperature as the semiconductor wafers, the semiconductor material can also be deposited on this inside surface, which interferes considerably with the functionality of the epitaxial reactor.

In another known type of epitaxial reactor (op. cit., pp. 160 and 162), the susceptor is plate-shaped and also supported rotatably in a bell. The induction heating coil is located on the bottom surface of the plate, and the semiconductor wafers lie on the top surface. The bell is surrounded a certain distance away by a reflector with sawtooth-like graduations. As in the previous example, this reflector sends the radiated heat back onto the semiconductor wafers.

In a third type of known epitaxial reactor (op. cit., p. 162), the semiconductor wafers are supported vertically as in the first example. Here, however, in contrast to the first example, their surfaces are parallel to the radial direction and not parallel to the lateral surface of the susceptor. In this third type of known epitaxial reactor, the bell holding the susceptor is surrounded by a resistance heating unit, extending essentially around the lateral surface of the bell.

Finally, an epitaxial reactor is known (compare DE OS 35 35 870) in which, as in the first type described above, the semiconductor wafers are supported on the outer lateral surface of a susceptor with a polygonal cross section. Several shields are arranged around the bell to reflect the emitted radiation back onto the semiconductor wafers

Common to all these known epitaxial reactors is that special measures must be taken to coat the bell or to use additional reflectors and shields to guarantee the most uniform possible temperature distribution over the individual wafers and to minimize the heat loss.

The task of the present invention is now to improve the device and the process of the type described above in such a way that, with the least possible effort and especially without the need for any of the additional measures indicated above such as reflectors, infrared lamps, infrared radiators, etc., it is possible to heat the semiconductor wafers without producing any mechanical or thermal stresses in them.

In the case of a device according to the introductory clause of Claim 1 and in the case of a process according to the introductory clause of Claim 10, this task is accomplished according to the invention by the features of the characterizing clauses of those claims.

In an inventive device, therefore, in a complete departure from the previous state of the art, the semiconductor wafers are supported not on the outer lateral surface of the susceptor but rather on the inner lateral surface, so that they mirror each other. If the susceptor has, for example, a hexagonal cross section, the semiconductor wafers can then be easily mounted in such a way that the free surface of one semiconductor wafer is directly opposite the free surface of another semiconductor wafer.

Thus essentially all of the thermal radiation emitted by a semiconductor wafer is cast upon the opposite semiconductor wafer, so that all of the semiconductor wafers can be heated up extremely uniformly and without any significant heat loss. No additional reflectors or holders which could interfere with the uniformity of the gas flow are required. The gas flows extremely uniformly through the interior space of the susceptor, on the inside surface of which the semiconductor wafers are supported. These can be mounted by means of a robot.

Advantageous elaborations of the invention can be derived in particular from Claims 2-9 and from Claim 11.

The invention is explained in greater detail on the basis of the drawings:

Fig. 1 shows a cross section through the inventive device; and
Fig. 2 shows a top view of the device according to Fig. 1 on a reduced scale.

Fig. 1 shows an epitaxial reactor with a susceptor 1 of graphite, which is coated on both sides with a thin film of silicon carbide to ensure that no interfering foreign material is absorbed by the susceptor 1 and released by it again later ("degassing effect"). On the inside lateral surface of the susceptor 1, semiconductor wafers 2 of silicon are mounted. These semiconductor wafers 2 can be introduced into the susceptor 1 by a robot, for example.

At the top of the susceptor 1 there is a ring nozzle 3, serving as a gas inlet, in the form of a circular tube, in the bottom surface of which small holes are provided, a certain distance apart, to form the nozzle orifices. The process gas, i.e., hydrogen, silicon tetrachloride, dichlorosilane,

and doping gas, flows out of this ring nozzle 3 and into the interior of the susceptor 1 and thus flows across the semiconductor wafers 2 mounted on the susceptor's inner lateral surface.

In addition, a ring nozzle 4, designed in the same way as the ring nozzle 3, is provided for the purge gas, namely, nitrogen or hydrogen. This purge gas flows between the outside surface of the susceptor 1 and the inner lateral surface of a container in the form of a quartz cylinder 5, which surrounds the susceptor 1, leaving a certain gap. The ring nozzles 3, 4 form a gas inlet device for supplying gas to the container. At the bottom of the susceptor, gas outlets 6 are provided, through which the process gas can leave the susceptor 1 and enter the space between the outside surface of the susceptor 1 and the inner lateral surface of the quartz cylinder 5. There the process gas mixes with the purge gas flowing into the space between the outer lateral surface of the susceptor 1 and the inner lateral surface of the quartz cylinder 5, and the mixture of the two gases can now leave the reactor via quartz tubes 7, serving as a gas outlet, to which a vacuum pump can be attached, if desired.

The susceptor 1 is supported rotatably above a quartz plate 8 and is rotated by a motor 9, acting by way of a reducing gear 10.

The top and the bottom of the quartz cylinder 5 are closed off by high-grade steel plates 11, 12. A cooling channel 13, through which a coolant flows to cool a seal 14 between the lower flange of the quartz cylinder 5 and the high-grade steel plate 11 at the bottom, is provided in the steel plate 11.

In a similar manner, the upper high-grade steel plate 12 has a cooling channel 15, which cools the seal 16 between the high-grade steel plate 12 at the top and a quartz cover 18 and . . . [the seal 17 – JPD] . . . . between the steel plate 12 and the upper flange of the quartz cylinder 5.

The outer lateral surface of the quartz cylinder 5 is surrounded by an induction heating coil in the form of a high-frequency coil 19,which is attached to a holder 20.

During low-pressure epitaxial processes, a vacuum on the order of 23,300 Pa (175 torr) to 26,600 (200 torr) is maintained in the interior of the quartz cylinder 5 and thus also in the interior of the susceptor 1 by a vacuum pump. The high-frequency coil 19 heats the susceptor 1, which is made of graphite and which is coated on both sides with silicon [i.e., silicon carbide? – JPD] films. Process gas is introduced through the ring nozzle 3 into the interior of the susceptor 1, on the inner lateral surface of which the semiconductor wafers 2 have been mounted by a robot.

Simultaneously, purge gas is introduced into the interior of the quartz cylinder 5 through the ring nozzle 4.

Of course, these steps are not carried out until after the semiconductor wafers 2 have been heated up by the high-frequency coil 19 to a temperature suitable for the epitaxial process. During the epitaxial process, the susceptor 1 is rotated by the motor 9 by way of the reducing gear 10, so that all of the semiconductor wafers 2 are exposed extremely uniformly to the induction heating by the high-frequency coil 19.

The susceptor 1 has a rectangular cross section, so that each of the individual semiconductor wafers 2 is directly opposite another semiconductor wafer. This ensures that most of the heat emitted by a semiconductor wafer strikes the opposite wafer. As a result, the individual semiconductor wafers 2 are heated up as uniformly as possible, and no special additional reflectors are needed. Through the arrangement of the semiconductor wafers 2 in the interior of the susceptor 1, furthermore, it is guaranteed that no parts of the reactor are exposed to the process gas except those on which the semiconductor wafers are located. In other words, there are no gas-exposed parts of the reactor which are at a higher temperature [than the wafers – JPD], which means that no additional measures must be taken to cool the inside wall of the quartz cylinder 5, for example.

In place of a susceptor with a hexagonal cross section, it is also possible, of course, to use a susceptor which has an even number of corners [other than 6 – JPD]. The only important point is that each semiconductor wafer must be directly opposite another semiconductor wafer, the surfaces of these wafers being as parallel to each other as possible.

So that the individual semiconductor wafers 2 can be held in place more effectively, the walls of the susceptor 1 are slanted slightly from top to bottom, the susceptor 1 thus having a larger cross-sectional area at the top than it does at the bottom. This causes virtually no impairment, however, to the parallelism of the surfaces of opposing semiconductor wafers 2

The invention thus creates an epitaxial reactor which is characterized by numerous advantages:

(a) To ensure the stress-free growth of the epitaxial layers, no special measures must be taken to achieve the most uniform possible heating of the semiconductor wafers by reflection of the thermal radiation, because this reflection function is fulfilled by the opposing surfaces of the semiconductor wafers themselves.

(b) Because the semiconductor wafers are mounted in the interior of the susceptor 1, it is ensured that there are no process gas-exposed parts of the susceptor which are at a higher temperature than the semiconductor wafers 2. This means in turn that no additional cooling measures must be taken to prevent undesirable deposition of semiconductor material on parts which are even hotter than the wafers 2.

(c) The epitaxial reactor can be easily loaded with semiconductor wafers by removing the quartz cover 18 and by programming a robot, for example, to introduce the semiconductor wafers 2 into the interior of the susceptor 1.

Claims

1. Device for the epitaxial deposition of material, especially semiconductor material, onto wafers (2) from the gas phase, with:

– a container (5), in which a vacuum can be produced;

– a susceptor (1), arranged in the container (5), to hold the wafers (2);

– a gas inlet device (3, 4) for supplying gas to the container (5);

– a gas outlet (7); and

– an induction heating coil (19) for heating the susceptor (1) and the wafers (2) in the interior of the container (5),

characterized in that:

– the wafers (2) are arranged in the susceptor (1) in such a way that the free surface of each wafer is essentially parallel to the free surface of an opposite wafer, so that the radiation directed onto one wafer and reflected from it is cast onto the other wafer and vice versa.

2. Device according to Claim 1, characterized in that the wafers are mounted on the inside walls of the susceptor (1).

3. Device according to Claim 2, characterized in that the cross section of the susceptor (1) has the form of a regular polygon with *n* corners, where *n* is preferably an even number.

4. Device according to Claim 3, characterized in that $n = 6$.

5. Device according to one of Claims 1-4, characterized in that the susceptor (1) is coated on both sides with silicon carbide.

6. Device according to one of Claims 1-5, characterized in that the susceptor (1) is supported rotatably in the container (5).

7. Device according to one of Claims 1-6, characterized in that the susceptor (1) is made of pure graphite with a silicon carbide coating.

8. Device according to one of Claims 1-7, characterized in that the gas inlet device (3, 4) has a gas inlet for supplying purge gas to the container (5) and a gas inlet (3) for supplying process gas to the susceptor (1).

9. Device according to one of Claims 1-8, characterized in that the inside walls of the susceptor (1) slant slightly inward from top to bottom.

10. Process for the epitaxial deposition of material, especially semiconductor material, onto silicon wafers (2) from the gas phase, in which:

– atmospheric pressure prevails in a container (5), but a vacuum can also be produced;

–wafers are supported in a susceptor (1) arranged in a container (5);

– gas is introduced into the container (5) through a gas inlet device (3, 4); and

– the wafers in the interior of the susceptor (1) are heated by an induction heating coil (19),

characterized in that

– the wafers (2) are arranged in the susceptor (1) in such a way that the free surface of each wafer is essentially parallel to the free surface of an opposite wafer, so that the radiation striking one wafer is reflected from it and cast back onto the other wafer and vice versa.

11. Process according to Claim 10, characterized in that both atmospheric pressure and a negative pressure of 23,300-26,600 Pa are maintained in the container (5).

One page of drawings attached.

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VERTICAL CVD REACTOR

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Claims

1. A vertical CVD reactor characterized in that a cooling tube is provided at the center of a vertically placed reaction tube along its axial direction, an annular wafer supporting body is provided so as to surround said cooling tube, a heating means is provided on the outer side of said cooling tube, and the inner circumferential surface of said supporting body that faces the aforementioned cooling tube is used as a wafer mounting surface.

2. The vertical CVD reactor described under Claim 1, characterized in that heating by the aforementioned heating means is realized by means of resistance heating.

3. The vertical CVD reactor described under Claim 1, characterized in that the aforementioned cooling tube runs through a base on which the reaction tube is placed, the top part of said cooling tube being positioned in an inner upper area of the reaction tube.

4. The vertical CVD reactor described under Claim 1, characterized in that the aforementioned cooling tube runs through the upper part of the reaction tube, and the bottom part of said cooling tube is placed in an inner lower area of the reaction tube.

5. The vertical CVD reactor described under Claim 1, characterized in that the aforementioned cooling tube runs through the reaction tube in the vertical direction.

6. The vertical CVD reactor described under Claim 1, characterized in that an upper cooling tube is provided at the top of the reaction tube.

Detailed explanation of the invention

Technical field

The present invention pertains to a vertical CVD reactor, wherein a reaction gas is introduced into a reaction tube in order to form a film on a wafer mounted on a supporting body.

Prior art and problems thereof

In the case of a recent method for depositing an epitaxial film on a composite semiconductor, a metallic metal (MO) gas, is used whereby a good quality film is deposited using a CVD (Chemical Vapor Deposition) method and is used for a laser, a high-speed memory, and an FET, for example.

Because an MO gas is immediately disintegrated by heat, it is desirable to heat only the wafer mounted on a wafer supporting body, such as a susceptor or a board. From this viewpoint, what is a so-called cold wall method, which involves induction heating utilizing an RF (Radio Frequency) coil or heating by means of an infrared lamp, is widely adopted.

A heating method based on the so-called hot wall method involving resistance heating is difficult to use in reality because thermal disintegration occurs quickly especially when an MO gas is used as described above, and the reaction gas adheres to various parts inside the reaction tube, resulting in the so-called snowflake problem.

On the other hand, induction heating utilizing an RF coil has problems in that it is inferior to resistance heating in terms of temperature uniformity, and in that its power efficiency is also poorer.

Horizontal type and vertical type reaction tube structures are known involving an RF heater or a lamp depending on how the reaction tube is placed. Here, the vertical type is

advantageous in that it offers better wafer housing efficiency. Said vertical type can be further classified into an inner heating type, wherein a heater or a lamp is provided in the vertical direction of the reaction tube, an annular susceptor is placed at the center part via a quartz tube, and its outer circumferential surface is used as a wafer mounting surface, and an outer heating type, wherein a heater or a lamp is provided outside the reaction tube, and a tilted outer surface of a susceptor provided inside the reaction tube is used as a wafer mounting surface.

In the case of the aforementioned inner heating type, when the process temperature on the wafer surface is brought to 650°C or so, the heater temperature is then 1300°C or so, which poses a risk to the quartz tube provided outside the heater, so that safety cannot be assured when AsH_3 or PH_3 is used. In addition, the heater-top temperature is also high, that is, 300°C or so at the gas entrance, resulting in the possibility that the gas may disintegrate before it reaches the wafer.

On the other hand, the outer heating type has a problem that a film accumulates on the surface of the quartz to make it foggy, so that the wafer temperature is unstable.

Objective of the invention

The present invention was devised in light of the aforementioned various situations, and its objective is to improve the conventional vertical structure so as to present a vertical CVD reactor suitable for depositing a film on a wafer using an MO gas with which reactor temperature uniformity and device safety can be assured, and with which a similar level of effect to that of the cold wall method can be achieved even when an outer heating type resistance heating method is utilized while attaining good power efficiency.

Outline of the invention

In order to achieve the aforementioned objective, the present invention proposes a vertical CVD reactor in which a cooling tube is provided at the center of a vertically placed reaction tube, an annular wafer supporting body is provided so as to surround said cooling tube, a heating means in the form of a so-called outer heating type is provided outside said cooling tube, and the inner circumferential surface of the supporting body that faces the aforementioned cooling tube is used as a wafer mounting surface.

According to the aforementioned configuration, because the cooling tube is provided at the center part of the reaction tube, the reaction gas introduced from above the reaction tube can be led to the wafer reliably without disintegration in the space created at the center part before it reaches the wafer, and the wafer itself can be heated sufficiently using an outer heating type heating means via the supporting body. Thus, resistance heating can be adopted for said heating means in place of RF coil-based induction heating, so that although it is a hot wall method, a

similar effect to that of the cold wall method can be achieved. As a result, a vertical CVD reactor suitable for film formation using an MO gas is obtained.

A variety of application examples of the present invention shown in figures will be explained below.

Application examples

First, in the first application example shown in Figure 1, 10 represents a quartz reaction tube provided vertically on base 12 via gasket 11 at its base part in a detachable fashion using clamp 14; 16 represents a center cooling tube provided inside reaction tube 10 so as to run through base 12 via gasket 13 along the center axial line in the vertical direction of said reaction tube 10; 18 represents an annular wafer supporting body referred to as a susceptor or a board made of graphite so as to surround said cooling tube 16 inside reaction tube 10; 20 represents a coil heater that is wound around the outside of reaction tube 10 so as to constitute an outer heating type heating means while it is covered by heater cover 22 and connected to power supply 24 so as to transmit heat when it is heated by means of resistance heating; and 26 represents a rotary drive mechanism for rotating wafer supporting body 18 around the center axis line of reaction tube 10 and cooling tube 16.

Rotary drive mechanism 26 is configured with rotary member 30 that is fixed to the base of leg 28 of supporting body 18 while provided with engagement gear part 30a on its periphery, supporting frame 34 fixed to base 12 so as to support said rotary member 30 via bearing 32, drive gear 36 that engages with engagement gear part 30a of rotary member 30 from outside, drive shaft 38 that supports said gear 36 by one end while extending outside reaction tube 10 through base 12 via gasket 37, and external motor 42 that transmits a driving force to said shaft 38 via coupling 40.

That is, when motor 42 rotates, its turning force is transmitted to rotary member 30 via drive shaft 38 and gear 36, and wafer supporting body 18 is rotated as a result.

Water or a gas as a cooling material is introduced into aforementioned cooling tube 16 through inlet 44. Pipe 46 is inserted deep into said cooling tube 16 in order to maintain the level of the cooling material inside tube 16, and the cooling material is discharged from the top of pipe 46 through outlet 48 created at the bottom. Curved top part 16a of cooling tube 16 extends to an upper area inside reaction tube 10 in order to guide a flow of gas smoothly from reaction gas inlet 50 created at the upper center of reaction tube 10. Here, gas outlet 51 is created on base 12.

Upper cooling tube 52 for cooling the upper area inside said tube is formed at the top of reaction tube 10, and cooling water supplied into said tube 52 through inlet 54 is discharged through outlet 56. In this case, a gas may be used as the cooling material.

Wafer supporting body 18 is formed into the shape of a polygonal plane with inner circumferential surface 18 [sic; 18a] tilted with respect to cooling tube 16, and said inner circumferential surface 18 is configured to serve as a mounting surface for wafer W. On the other hand, outer circumferential surface 18b of supporting body 18 is formed into the shape of a circular plane and is placed at the smallest possible distance from the inner circumferential surface of reaction tube 10.

In the vertical CVD reactor configured in the aforementioned manner, the reaction gas, such as an MO gas, is introduced into reaction tube 10 through gas inlet 50 and is led between said cooling tube 16 and wafer mounting surface 18a of supporting body 18 while being led around top part 16a of center cooling tube 16 in order to form a prescribed film on wafer W, and the post-reaction gas is exhausted outside through gas outlet 51 when it flows further down.

Therefore, the reaction gas is cooled at center cooling tube 16 and upper cooling tube 52 before it reaches wafer W from gas inlet 50. Thus, even when outer heating type coil heater 20 utilizing resistance heating is used, the temperature increase can be restrained, so that a similar effect to that of the cold wall method can be achieved.

Furthermore, a design that does not require upper cooling tube 52 is feasible depending on how well a cooling effect can be attained using center cooling tube 16. The cooling effect is achieved mainly by center cooling tube 16, and upper cooling tube 52 supports said function.

Regarding the aforementioned wafer film formation function, rotary drive mechanism 26 is responsible for rotating supporting body 18 in order to improve the uniformity of the film formation.

Next, for the second application example of the present invention shown in Figure 2, components corresponding to those in the first application example are assigned with the same reference numbers, and only different components will be explained below.

In the second application example, center cooling tube 16 extends inwardly from the top of reaction tube 10, and bottom part 16b of cooling tube 16 runs through the center part of annular wafer supporting body 18 and reaches a lower area of reaction tube 10 close to base 12.

Cooling water or gas is introduced through the inlet at the top of pipe 46 and is discharged through the outlet created at the top of the tube 16.

In this case, inlet 50 for the reaction gas is configured with multiple pipes, which run through upper cooling tube 52, on the top of reaction tube 10 at positions offset from cooling tube 16 provided at the center portion.

Next, for the third application example of the present invention shown in Figure 3, components corresponding to those in the first and second application examples are assigned with the same reference numbers, and only different components will be explained below.

In the case of the third application example, a configuration in which center cooling tube 16 is provided at the center part of reaction tube 10 while running through it vertically is shown, wherein the bottom part runs through base 12 via gasket 13 in the same manner as in the first application example, the top part runs through the center part of cooling metal flange 60 via gasket 62, and water or a gas for cooling is passed through the inside of the tubular part constantly in one direction as indicated by arrows. Cooling metal flange 60 serves both the cooling function of upper cooling tube 52 in the aforementioned application examples and the function of a cap that closes off the top part of reaction tube 10 via gasket 63. Multiple reaction gas inlets 50 can be provided on said flange 50 [sic; 60].

Here, for upper cooling tube 52, it is also feasible to provide another cooling unit outside the top part of the reaction tube to replace the configuration of the first and second application examples in which it is formed as one body with the top part of reaction tube 10.

Figure 4 shows a modified configuration of center cooling tube 16 based on the configuration of the second application example.

Here, cooling chamber 16a is provided separately inside center cooling tube 16, wherein said cooling chamber 16[a] is formed in an annular shape along the inner wall of cooling tube 16, and its height is slightly offset upwardly with respect to wafer W mounted on supporting body 18; that is, its positional relation to wafer W in the vertical direction is offset upwardly. This is done considering the configuration wherein wafer W is placed with a tilt so that its lower part is thus placed closer to cooling tube 16 than its upper part and considering the temperature distribution in the longitudinal direction of wafer W. When said configuration is adopted, a uniform even temperature distribution can be achieved.

Furthermore, the cooling water or gas is introduced into cooling chamber 16a by pipe 46a that is inserted deeply into cooling chamber 16a, and it is discharged through pipe 46b connected to the top part of cooling chamber 16a.

Figure 5 shows a modified configuration of wafer supporting body 18, wherein protrusion 18c is formed at the top of outer circumferential surface 18b of supporting body 18 that faces reaction tube 10, that is, the side where reaction gas indicated by an arrow flows into gap 70 formed between reaction tube 10 and outer circumferential surface 18b of supporting body 18, along the entire outer circumference.

As such, gap 70 is very small, and the flow of reaction gas into gap 70 is restricted, so that the thermal transmission efficiency can be further improved.

Figure 6 and Figure 7 show split structures for supporting body 18 that simplify the mounting/removal of wafer W with respect to supporting body 18.

In the first through third application examples, the fact that clamp 14 is released and reaction tube 10 is hoisted from base 12 when mounting wafer W on supporting body 18 is the

same as that with a conventional vertical structure. However, in the present invention, because wafer W mounting surface 18a is provided inside, it is possible that mounting of said [wafer] may be difficult due also to the presence of center cooling tube 16.

Therefore, to simplify this, as shown in Figure 6, a split structure comprising part A and part B is adopted to configure wafer supporting body 18, and opening at vertical hinge part C in the direction indicated by an arrow is implemented when mounting wafer W.

In addition, as shown in Figure 7, it is also feasible to adopt a configuration in which wafer supporting body 18 is divided into multiple split parts A, B, C, D ... that can be unfolded radially with respect to the base part or the center part.

Application examples and modification examples have been explained above. In the present invention, because outer circumferential surface 18b of supporting body 18 is positioned parallel to the inner circumferential surface of reaction tube 10, a larger heating area can be realized than with the conventional vertical type in which the wafer is mounted on the outer circumferential surface of the susceptor, and a heater temperature of 800°C or lower is sufficient when the wafer surface is to be heated to 650°C. As such, there is no risk of damage to the quartz reaction tube, so that a high level of stability can be attained.

In addition, because the center cooling tube can be easily heated to 1000°C or higher when it is not cooled, cleaning for defogging of the quartz and so-called board bake cleaning for removing absorbed gas can be carried out easily by taking advantage of said high temperature, which offers an additional effect.

Furthermore, although a wafer supporting body with a rotating configuration was shown in the application examples, a fixed type may be utilized also. In addition, the outer heating type heating means may be replaced with heating using an infrared ray lamp, for example.

Above the present invention has been described using application examples, but the embodiments are not limited to this.

Effect of the invention

As described above, because the present invention has a configuration in which the cooling tube is provided at the center of the reaction tube, the annular wafer supporting body is provided around it, the sufficient resistance heating type heating means is provided outside the reaction tube, and the inner circumferential surface of the supporting body facing the cooling tube is used as the wafer mounting surface, the reaction gas introduced into the reaction tube can be supplied to the wafer reliably without being disintegrated. In addition, because the wafer can be heated with outer heating type resistance heating, temperature uniformity and power efficiency as advantages of the hot wall method can be improved while solving the shortcomings of the hot wall method, and the wafer can be heated in a similar manner as with the cold wall

method, so that a vertical CVD reactor suitable particularly for wafer film formation using an MO gas can be presented.

Brief description of the figures

Figure 1, Figure 2, and Figure 3 are vertical cross-sectional views of the first, the second, and the third application examples of the vertical CVD device of the present invention, respectively. Figure 4 and Figure 5 are partially enlarged views of partially modified configurations of the present invention, respectively. Figure 6 and Figure 7 show different split structures of for the wafer supporting body, respectively.

10	Reaction tube
12	Base
16	Center cooling tube
18	Wafer supporting body
20	Coil heater
26	Rotary drive mechanism
50	Gas inlet
51	Gas outlet
52	Upper cooling tube

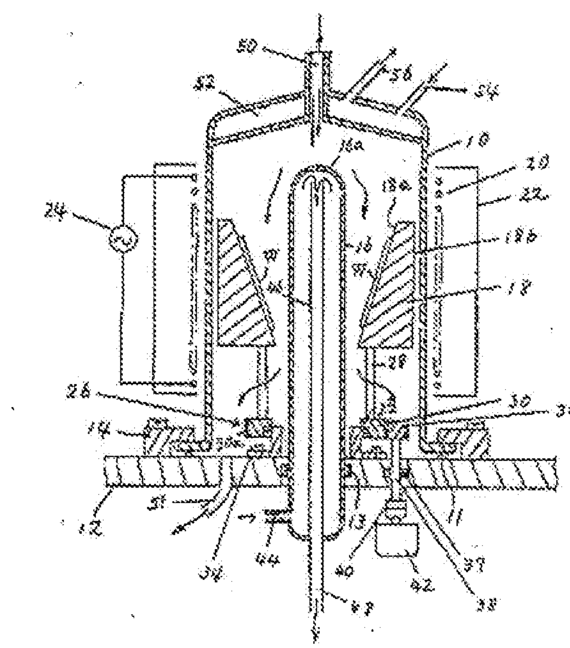

Figure 1

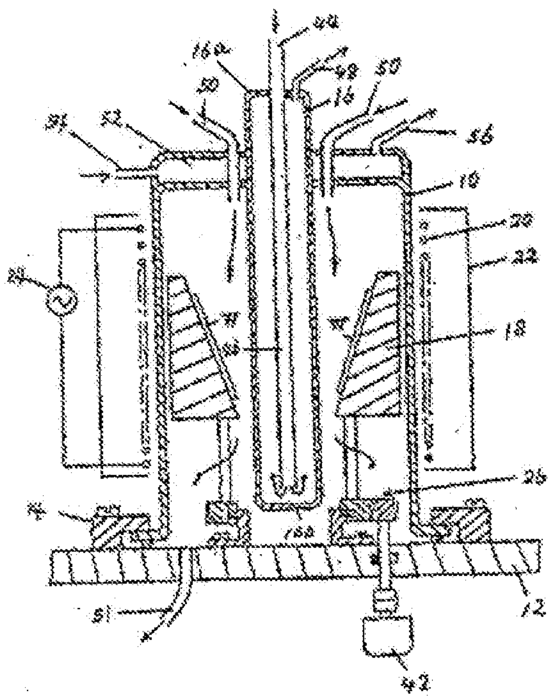

Figure 2

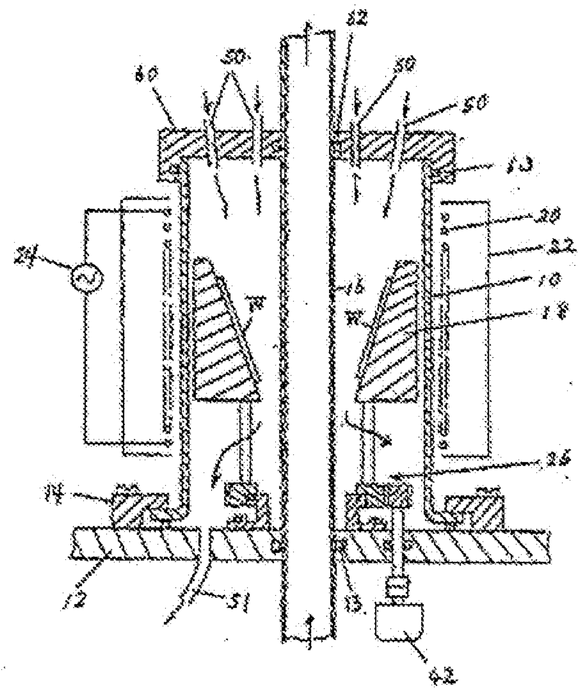

Figure 3

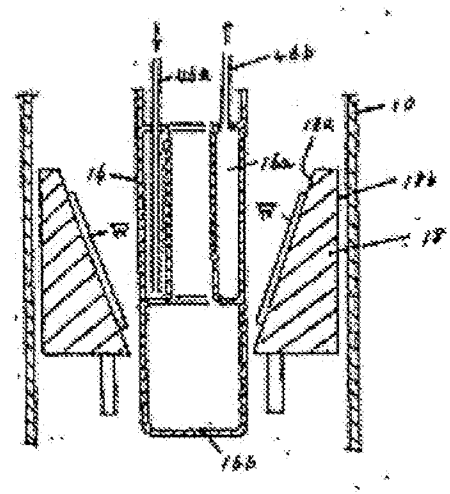

Figure 4

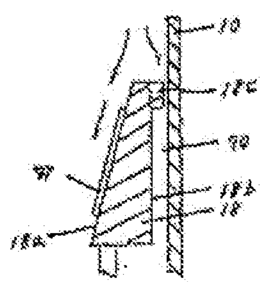

Figure 5

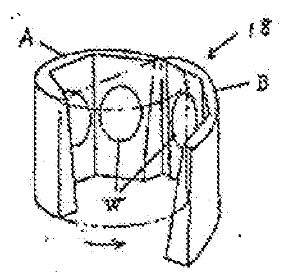

Figure 6

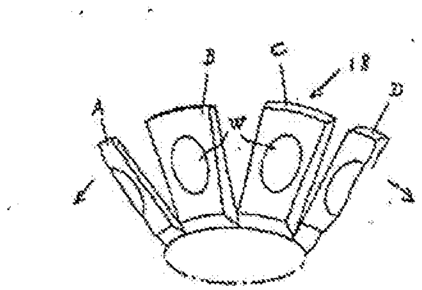

Figure 7